AEROPROPULSION ENVIRONMENTAL TEST FACILITY

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ABSTRACT

As part of the DoD Base Realignment and Closure process, the unique Navy capability to test aircraft engines under various environmental conditions is being transitioned to the Air Force. A new facility, using two modified sea-level Air Force T-9 test cells as building blocks, formed the basis of the new design. The structural design of the test cells and test control building was based on the aerodynamic and acoustic requirements for testing large afterburning turbojet/turbofan engines. Major construction has passed the 90-percent completion milestone. Aerodynamic criteria were defined in 1/12th-scale model tests of an engine installation using an F110 engine simulator. Modifications were then made to the basic T-9 test cells to allow ram air duct direct-connect capability. Following construction, activation/validation of the test facility will be conducted with an actual F110 engine, run in both direct-connect and bellmouth inlet configurations. Initial Operational Capability is scheduled for September 1998. Technical aspects of the facility design, construction, and ram air duct are described. Final system capabilities are airflow of 550 lb/sec; inlet air temperature range of –65 to 260°F; and inlet air pressures up to 32 psia (1.1 Mach number). Environmental conditions of high and low temperature, water and ice ingestion, sand ingestion, and salt air corrosion can be duplicated. Engine transient operation, and mission profile endurance tests with simulated inlet conditions of forward flight velocities will be available to both government and industry users.

NOMENCLATURE

A/E	Architect-Engineer
AARL	Aeronautical and Astronautical Research Laboratories
AEDC	Arnold Engineering Development Center
AFB	Air Force Base
ASMET	Accelerated Simulated Mission Endurance Tests
ASTF	Aeropropulsion Systems Test Facility
BRAC	Base Realignment and Closure
dB	Decibels
DoD	Department of Defense
IOC	Initial Operational Capability
NAWC	Naval Air Warfare Center
NAWCAD	Naval Air Warfare Center, Aircraft Division
NAWCADTRN	Naval Air Warfare Center, Aircraft Division Trenton
RAMP	Requirements, Analysis and Management Plan
SAE	Society of Automotive Engineers

INTRODUCTION

The Naval Air Warfare Center (NAWC), located in suburban Trenton, New Jersey, has been a facility for the research, development, test and evaluation of airbreathing propulsion systems. Test facilities existed that could simulate any atmospheric condition an aircraft powerplant may encounter in flight. The Center's efforts in the areas of propulsion research and related fields have advanced the current state of the art, resulting in lighter, more efficient, and more reliable propulsion systems.

Located between Nashville and Chattanooga, TN, is the U.S. Air Force's Arnold Engineering Development Center (AEDC), Arnold Air Force Base. AEDC is divided into three functional areas, the Engine Test Facility, the Propulsion Wind Tunnel and the Von Karman Gas Dynamics Facility. AEDC conducts a wide range of tests and simulations in aerodynamics, propulsion, and aerospace systems. This paper addresses the transition of some of the Navy's propulsion large engine

tions in aerodynamics, propulsion, and aerospace systems. This paper addresses the transition of some of the Navy's propulsion large engine test capability to AEDC. The products of this effort are two large engine environmental test cells.

LARGE SEA LEVEL/ENVIRONMENTAL TEST CELL CAPABILITIES AT TRENTON

The 1W and 2W sea-level test cells at Trenton were used to conduct environmental engine testing. The purpose of the testing was to measure and collect data for risk assessments of engine design of medium-size turbine engines (on the order of those used in fighter aircraft). Test capability is needed to generate data in support of aircraft engine development, service life assessment, and fleet service problem investigation programs. The 1W and 2W test cells were constructed as sea-level exhaust test stands with ram air inlets. Tests conducted include accelerated, simulated mission endurance tests (ASMET), icing tests, corrosion tests, sand and water ingestion tests, and high- and low- temperature start tests. Control and data acquisition/processing rooms are an integral part of the test cell configurations, for directing and controlling the tests and to collect, process, and analyze the data.

Test equipment/material such as thrust stands, engine supports, valves and piping system components, instrumentation items and components, and display and control systems, have already been transferred to AEDC for use in the new SL2/SL3 facility.

TRANSITION TO AEDC

Requirements

The Navy requires that its aircraft turbine engine developments undergo evaluation at various operating environments simulated by salt air corrosion testing as well as icing testing, and maintain this capability at NAWCAD. The approach was to relocate two BRAC excessed test cells (A/F 32T-9 Noise Suppressor System equipment); install the test cells, ducting, thrust stands, salt spray generators, mixing equipment, process air blowers with electric motors and control centers, ducting valves, and fuel conditioning systems; and then verify construction and installation.

The in-cell ducting, salt spray mixers, and generators, two of the three required air compressors with electric motors and control centers, ducting valves, fuel conditioning systems, and test stands are existing items at NAWCADTRN, and will be transferred to AEDC. Salt air corrosion testing will be a new test capability for AEDC.

NEW FACILITIES - DESIGN CONCEPT TEST CELLS SL2/SL3

Figure 1 shows the design concept of the SL2/SL3 test cell facility as prepared by the architect-engineer (A/E) firm. The layout includes the two A/F32T-9 NSS test cells side by side, separated by the control room building. In the foreground are the ram air inlet ducts, the refrigeration turbine system, and the hydraulic control building. At the back end of the test cells are the exhauster stacks.

Figure 2 shows a cutaway view of an A/F32T-9 NSS test cell used as the building block of the new facility. It also identifies the major features of primary air intake, engine test section, exhaust gas augmentor, and exhaust stack.

ENVIRONMENTAL FACILITY MODEL TESTS

The baseline Air Force T-9 test cells were designed as demountable/movable facilities, and could be transferred to AEDC. Therefore, most of the aerodynamic and acoustical design effort concentrated on the modifications required to make the T-9 facilities suitable for Navy testing purposes. Since the T-9 was designed as an atmospheric test

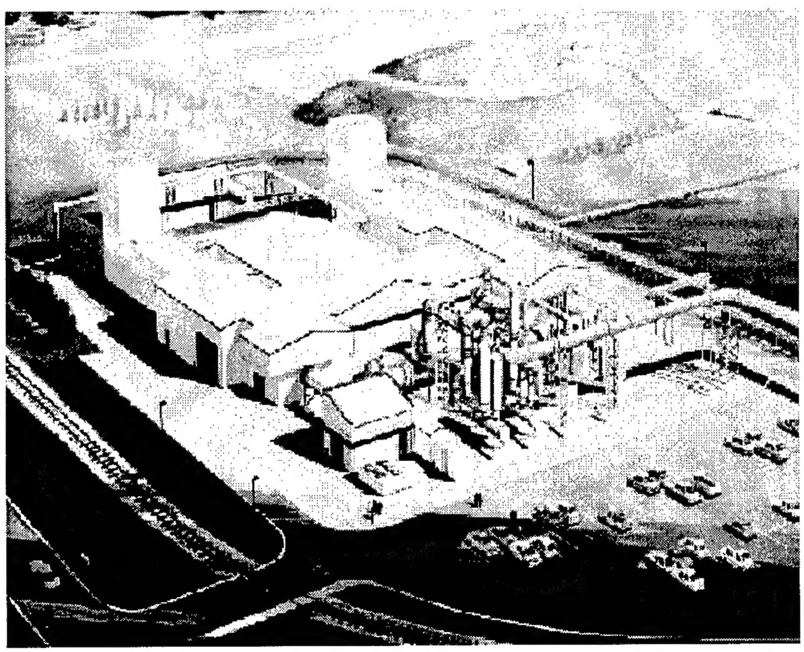

Figure 1. A/E concept design of test facility.

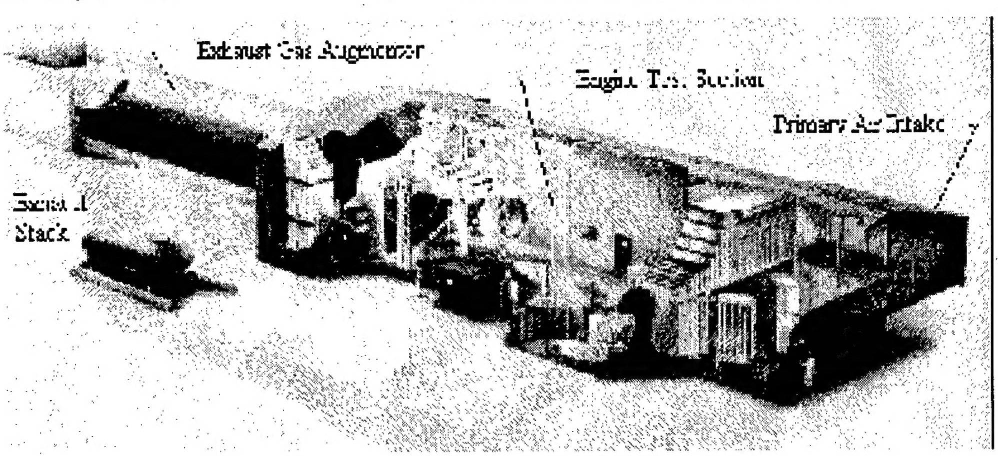

Figure 2. Cutaway view of A/F32T-9NSS.

cell, major modifications were needed to accommodate ram air and environmental test capabilities.

Two scale-model tests were conducted to identify and evaluate the modifications required to accommodate ram air testing in the T-9, and to determine the airflow treatment required to bring the T-9 front cell velocity distortion down to the level of the Trenton test cells. A 1/12th- scale model study of the T-9 test cell with F110 engine simulators was conducted at Ohio State University Aeronautical and Astronautical Research Laboratory in Columbus, OH. Test techniques were consistent with the guidelines of Ref. 1. An illustration of the model setup is shown in Fig. 3. The purpose of the Phase I test was to develop and evaluate ways of adding ram air hardware to the baseline T-9 while concurrently improving airflow quality to a comparable level with Trenton. Various alternative configurations were selected and constructed.

The objectives of Phase II were to evaluate changes proposed to the atmospheric testing configuration based on the Phase I tests; measure internal ram air duct airflow quality for engine operating conditions up to the full-scale corrected flow of 249.48 kg/sec; and determine ram air duct/plenum geometry from the flow mixing header downstream to the engine.

Analysis of the results of the model tests led to the following recommended improvements:

- **Ram Air Modifications** To meet the ram air testing requirements, the T-9 will be modified to accommodate an 2.44-m ram air delivery plenum through the front cell wall. The 2.44-m plenum will reduce down to a 1.52-m direct-connect pipe just upstream of the primary intake acoustic baffles, and penetrate the acoustic baffles at the engine centerline. The 1.52-m ram air pipe will terminate with a blank-off plate 3.05 m downstream of the primary intake baffles. The cell can perform atmospheric testing with the blank-off plate installed, or ram air testing with the blank-off plate removed and the direct-connect hardware installed. Additionally, the exhaust collector intake lip will be modified to accept direct connect exhaust for environmental/ corrosion testing.

- **Air Flow Modifications** – The baseline T-9 has substantially greater front cell velocity distortion [FC_d = (Vmax - Vmin)/Vavg] than measured in 1W/2W at NAWCADTRN (115 percent versus 50 percent). In order to reduce the front cell velocity distortion in the T-9 to 1W/2W levels and to minimize the distortion caused by the ram air plenum and duct, two (2) flow-smoothing screens will be installed in the modified T-9, one each upstream and downstream of the primary intake acoustic baffles. These flow-smoothing screens will reduce the front cell velocity distortion from 115 percent in the baseline T-9 to 45 percent in the modified T-9. The modified T-9 will then duplicate the atmospheric testing front cell velocity quality of the 1W/2W facility.

- **Cell Operation and Maintenance Issues** – The baseline T-9 test cells have two exhaust system problems that needed correction in order to duplicate the NAWCADTRN test capability. The T-9 test cell has high levels of low-frequency vibration (> 110 dB). Past experience has shown that low frequency levels over 100 dB can cause physical damage to adjacent structures and equipment; in this case, the control room/ancillary buildings and equipment as shown in Fig. 1. Existing maintenance problems with the exhaust system of the baseline T-9 will be accentuated by environmental testing in the modified T-9. The perforated liner and liner acoustic fill deteriorate during afterburner operation, and are expected to suffer additional deterioration due to high heat loads during ram air afterburning testing and corrosion/cold soak testing. The following solutions were developed to address these problems:

  — Replace the existing perforated acoustic augmentor tube with a non-perforated, hard augmentor tube of identical interior geometry.

  — Enclose the new augmentor tube with a concrete enclosure.

  — Replace the acoustic baffle exhaust silencer with a tubular silencer package.

  — Replace the existing concrete stack with a larger and higher concrete stack that encloses the new tubular exhaust silencer package.

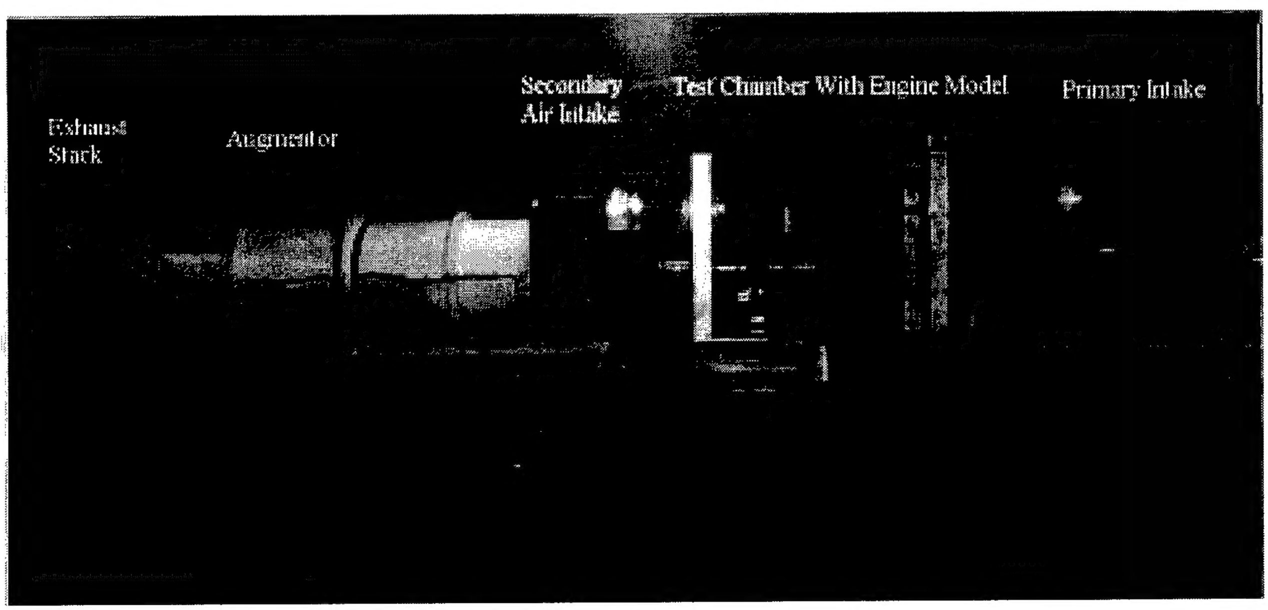

Figure 3. Scale model test setup.

These modifications will also reduce the overall exterior acoustic levels of the modified T-9 test cell.

The test techniques, methods of measurement, analysis parameters, and suggested modifications are consistent with the guidelines of SAE Aerospace Information Report 4869 - "Design Considerations for Enclosed Turbofan/Turbojet Engine Test Cells" (Ref. 2). The important factors of engine operational stability, aerodynamic performance, and acoustical control have been properly addressed. Test data and a discussion of the test model results are contained in the Ref. 3 report.

FULL-SCALE FACILITY CONSTRUCTION

Work Involved

In general, the construction of the SL2/SL3 facility consists of constructing two new sea-level environmental jet engine test facilities that are single-story, permanent, high-bay, blast-resistant construction structures that have reinforced concrete foundations, walls and roofs, and masonry walls. The major items of construction are as follows:

- Relocation, modification and re-installation at AEDC of two A/ F32T-9 NSS test cells
- Construction of control rooms between the two test cells
- Installation of various utility systems including:
  - — steam
  - — water/sewer
  - — gaseous nitrogen
  - — fuel
  - — electricity
- Installation of ram air ducting and support towers
- Installation of a compressor/blower as well as expansion joints/valves
- Installation of refrigeration turbines

Tempered air, hot or cold, will be supplied to the SL2/SL3 cells from existing ASTF plant facilities through about one-half mile of ducting. Primary conditioning of the air will take place at the SL2/SL3 test facility, where two expansion turbines will be used to further chill the air, and a mixing header will be used to blend hot and cold air to the required cell inlet temperature. Air flow and pressure will be regulated by control valves, and excess air will be dumped through the vent systems. A small blower system is being installed to supply air for dynamic soaks during corrosion tests.

Work is progressing toward the scheduled completion of construction of late April 1998 - early May 1998. Upon completion, the contractor, in conjunction with AEDC, will begin checking out the completed test facility. AEDC's activities will include installing instrumentation from the contractor-installed side of a panel to the termination point in a panel in the various plants. Once all of this has occurred, the activation-validation phase of the project will begin.

Figure 4 shows an aerial view of the facilities under construction in mid-July 1997. The view is looking to the northwest. Figure 5 shows the interior of Test Cell SL2 looking toward the augmentor. The thrust stand was a part of the new construction and duplicates the arrangement at Trenton.

Activation/Initial Operating Capability

The objective of the Activation and Validation is to test, initialize, and verify the systems of the facility following construction. Lessons learned from activation and validation of past complex AEDC projects show the need for a comprehensive management plan to guide these activities for the transitioned facilities. The overall facility requirements and acquisition management approach for design and construction of the facility are addressed in the project Requirements Analysis and Management Plan (RAMP).

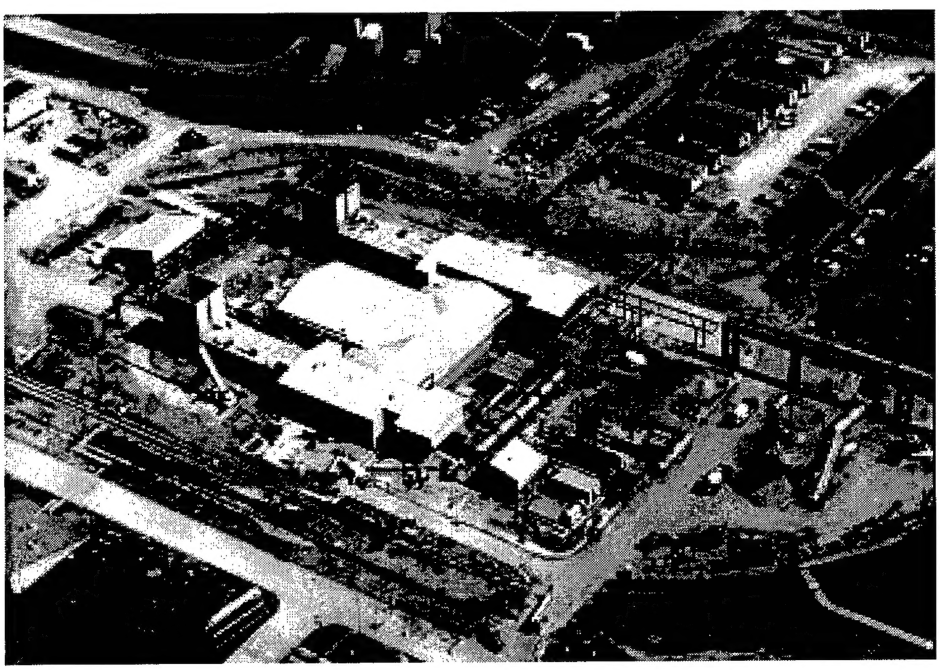

Figure 4. July 1997 construction.

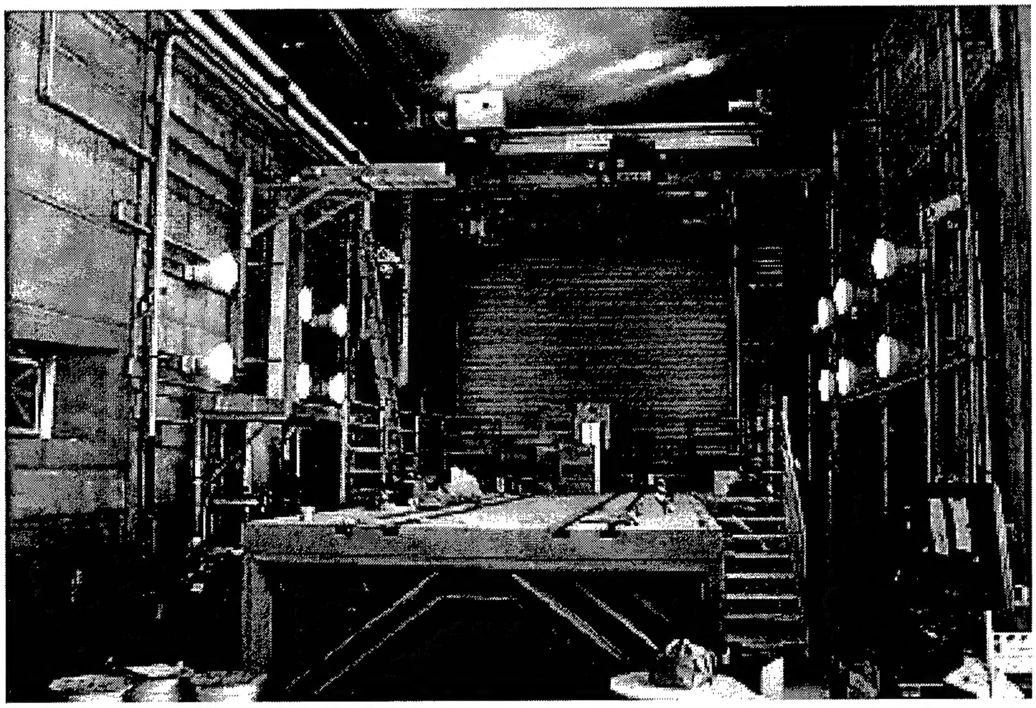

Figure 5. Interior of Test Cell SL2.

The scope of work begins with the preparation of systems activation plans and will be accomplished in two phases, defined as Activation and Validation. Validation will confirm the operation of the facility with the successful testing of an operational turbine engine. In the first test cell (SL2), a full-scale engine simulator will be run to verify operation and control of the air supply system. An F110-GE-100 engine will be run in the second test cell (SL3) in both bellmouth installation and direct-connect installation. Steady-state, transients, and ram conditions will be evaluated. The scope of work will end with the completion of the Validation phase which is defined as IOC.

STATUS

As this paper is prepared, construction of the SL2/SL3 test complex is approximately 90-percent complete.

FINAL SYSTEMS CAPABILITIES

Once the transition and transfer is successfully completed, the test cells will have the following system capabilities:

- SL2/SL3
  - Sea-level cells; 64.62m × 8.53 m × 7.93 m
    - 429.48 kg/sec airflow
    - 219 to 503 K
    - 206.85 kPa max. inlet (Mach 1.1)
    - Corrosion, icing, water, and transient capable
    - Control Room Complex (36.58 m × 18.9 m × 4.88 m)

SUMMARY

Both the Navy and the Air Force have world-class airbreathing propulsion test facilities. With the closure of the Navy's Trenton facilities, some of the physical facilities will be transferred to the Air Force at AEDC, and some to the Naval Air Station at Patuxent River, MD. Although Trenton will close in late 1998, the Navy's aircraft propulsion test capability will remain intact, but with operations at separate physical locations. The AEDC facilities will be utilized by the Air Force, Navy, and Army, and are also available to engine manufacturers and other commercial customers.

REFERENCES

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